ANSI C63.2-1996
(Revision of ANSI C63.2-1987)

American National Standard for Electromagnetic Noise and Field Strength Instrumentation, 10 Hz to 40 GHz—Specifications

Accredited Standards Committee
on
Electromagnetic Compatibility, C63

Accredited by the

American National Standards Institute

Secretariat

Institute of Electrical and Electronics Engineers, Inc.

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Abstract: Electromagnetic compatibility techniques and requirements for instruments measuring quasi-peak, peak, rms, and average values for electrical and electronic equipment for various applications are provided.
Keywords: electromagnetic compatibility, field strength instrumentation

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Introduction

(This introduction is not a part of ANSI C63.2-1996, American National Standard for Electromagnetic Noise and Field Strength Instrumentation, 10 Hz to 40 GHz—Specifications.)

Almost from the beginning of radio broadcasting, the electric utility companies were faced with problems of radio noise. In 1924 the National Electric Light Association appointed a committee to study the subject. The manufacturers of electric power equipment had encountered similar problems, and, in 1930, a subcommittee of the National Electrical Manufacturers Association (NEMA) Codes and Standards Committee was set up. The following year, the EEI-NEMA-RMA Joint Coordination Committee on Radio Reception was organized.

The Joint Coordination Committee issued a number of reports, among which was *Methods of Measuring Radio Noise, 1940*. This report included specifications for a radio-noise and field-strength meter for the frequency band 0.15–18 MHz. The report recommended procedures for measuring radio-noise voltage (conducted noise) from low- and high-voltage apparatus, making noise field-strength measurements near overhead power lines, determining broadcast field strengths, and collecting data upon which to base tolerable limits for radio noise. More than a thousand radio-noise meters were built, essentially in conformance with those specifications. They have been used to make extensive field, factory, and laboratory tests on many types of electrical apparatus.

During World War II, the needs of the armed services for instruments and methods for radio-noise measurement, particularly at frequencies higher than the broadcast band, became pressing and, in 1944, work on developing suitable specifications was begun by a special subcommittee of ASA Sectional Committee C63, Radio-Electrical Coordination. This subcommittee developed a wartime specification that became the joint Army-Navy Specification JAN-I-225, issued in 1945 and later approved as American War Standard—Method of Measuring Radio Interference of Electrical Components and Completed Assemblies of Electrical Equipment for the Armed Forces from 150 kc to 20 Mc, C63.1-1946. This American War Standard included the specifications for a radio-noise meter similar to those included in the JCC 1940 report with the addition of some refinements and improvements.

In 1950, the ASA Sectional Committee C63 completed preparation of Proposed American Standard Specifications for a Radio Noise Meter, 0.015 to 25 Mc/s, C63.2, which was published in March 1950 for trial and study. An effort was made to take advantage of the extensive experience with meters made under the specification in the 1940 report as well as advances in radio engineering practice.

Experience with the proposed standard indicated that a number of revisions and improvements were needed. The various branches of the Armed Forces had developed new specifications for radio-noise meters after 1950, and the International Electrotechnical Commission published for CISPR (International Special Committee on Radio Interference) *Specification for CISPR radio interference measuring apparatus for the frequency range 0.15 Mc/s to 30 Mc/s*, Publication 1, First edition, 1961. The revised standard was published as American Standard Specifications for Radio-Noise and Field Strength Meters 0.015 to 30 Mc/s, C63.2-1963. In 1964, standard C63.3, covering instruments for the frequency range 20 MHz to 1000 MHz was issued, which was based upon the principles of measurement used in standard C63.2. In 1977 CISPR Publication 16 was issued.[1]

The experience gained with the earlier specifications, and the desire to make this American Standard compatible with international standards, resulted in ANSI C63.2-1987, which also combined the earlier documents C63.2 and C63.3. This 1996 edition extends the frequency range down to 10 Hz to accommodate requirements for compatibility measurements at lower frequencies.

[1]See clause 2, References, for information on the current edition of this standard.

This standard was developed by Subcommittee One on Techniques and Developments of Accredited Standards Committee on Electromagnetic Compatibility, C63.

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American National Standard for Electromagnetic Noise and Field Strength Instrumentation, 10 Hz to 40 GHz—Specifications

1. Overview and scope

1.1 Introduction

The increasing significance of electromagnetic compatibility considerations in the design and application of electrical and electronic equipment is directly related to the expanding sophistication of the functions performed by such equipment in industrial, civilian, and military activities. In order to assure the designer and user that equipment of concern to them will function in the intended application, it is necessary to control the electromagnetic environment adequately. The environment will vary from one application to another, as will the performance requirements. For these reasons a variety of electromagnetic compatibility techniques and instruments are necessary. This standard describes requirements for instruments measuring quasi-peak, peak, rms, and average values. Which of these will be required in any one instrument will depend upon the application. (See also ANSI C63.5. [1])

The quasi-peak detector yields a measure roughly correlated with the subjective annoyance effect on AM broadcast services. It has also found restricted use for measuring interference in television.

The peak detector has been applied in those situations in which a very low repetition-rate pulse can produce significant effects, such as in the case of nonredundant data-transmission formats. Peak measurements are used for military and some industrial applications, including measurement of ignition interference.

The rms and average values are used extensively for environmental survey work. The interference frequently arises from numerous independent impulsive sources occurring at random. If the spectra of the sources are broadband and relatively flat and produce time responses that overlap in the intermediate frequency (IF) amplifier, the rms and average levels measured vary approximately as the square root of the bandwidth. For the case of non-overlapping responses, the rms indication still varies with the square root of the bandwidth, but the average value is independent of

[1]ANSI C63.5 is under revision; it is anticipated that a new edition will be published in 1996. For information, contact the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

bandwidth. The rms value is used for determining interference effects on some communication channels. The average value is widely used in measurements of AM emissions.[2]

1.2 Scope

This standard delineates the requirements of electromagnetic noise instrumentation for the frequency range of 10 Hz to 40 GHz incorporating quasi-peak, peak, rms and average detectors.

NOTE — Examples of the types of voltages, currents, and fields to be measured are unmodulated and modulated sinewaves, and components of electric and electromagnetic disturbances, including transients that may interfere with the operation of communication, electric, or electronic equipment.

The basic instrument is a frequency-selective voltmeter (FSVM). With appropriate coupling devices, such as antennas and current probes, the instrumentation will also measure other physical quantities such as field strength and current.

The parameters for the quasi-peak detector are specified to agree with the requirements of the Comité International Special des Perturbations Radioélectriques (International Special Committee on Radio Interference) (CISPR) [see CISPR Publication 16 (1987)]. An optional discharge time constant is also specified.

The requirements of this specification should not be construed to imply that one instrument is required to cover the entire frequency range or that the instrument is permitted to have only the specified detector or detectors. Many users have measurement requirements over a smaller frequency range or may require additional detection capabilities.

Although spectrum analyzers are frequently used in electromagnetic-noise measurements, it is not within the scope of the present standard to cover such instruments. A separate document covering spectrum analyzers for use from 20 Hz to 40 GHz is in preparation as a proposed supplement to this standard. However, a measuring set configured around a spectrum analyzer that meets the requirements of this standard may be used.

For measurements made on paired telecommunications lines, refer to IEEE Std 743-1984. Instrumentation specifications for measurement of telecommunications terminal equipment for compliance to technical standards of regulatory authorities are under consideration.

2. References

This standard shall be used in conjunction with the following publications. When the following standards are superseded by an approved revision, the revision shall apply.

ANSI C63.4-1992, American National Standard Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronics Equipment in the Range of 9 kHz to 40 GHz.[3]

ANSI C63.5, [4] American National Standard for Calibration of Antennas Used for Radiated Emissions Measurements in Electromagnetic Interference (EMI) Control.

ANSI C63.12-1987, American National Standard Recommended Practice for Electromagnetic, Compatibility Limits.[5]

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[2]Additional discussion of the application of various detectors is given in ANSI C63.12-1987 . (See clause 2 for information about references.)
[3]ANSI C63 publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA, or from the Sales Department, American National Standards Institute. 11 West 42nd Street, 13th Floor. New York, NY 10036, USA.
[4]See footnote 1.
[5]ANSI C63.12-1987 is currently under revision. For information about availability, contact the IEEE.

ANSI C63.14-1992, American National Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD) (Dictionary of EMC/EMP/ESD Terms and Definitions).

CISPR Publication 16-1 (1993), Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods, 1st ed.[6]

IEC 50 (161): 1990, International Electrotechnical Vocabulary, Chapter 161: Electromagnetic compatibility.[7]

IEEE Std 100-1992, The New IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).[8]

IEEE Std 291-1991, IEEE Standard Methods for Measuring Electromagnetic Field Strength of Sinusoidal Continuous Waves, 30 Hz to 30 GHz (ANSI).

IEEE Std 376-1976 (Reaff 1993), IEEE Standard for the Measurement of Impulse Strength and Impulse Bandwidth (ANSI).

IEEE Std 743-1984 (Reaff 1992), IEEE Standard Methods and Equipment for Measuring the Transmission Characteristics of Analog Voice Frequency Circuits (ANSI).

SAE-ARP-958, Electromagnetic Interference Measurement Antennas; Standard Calibration Requirements and Methods (November 1992).[9]

UL 1244, Electrical and Electronic Measuring and Testing Equipment, 3rd ed., 1993.[10]

UL 3111-1, Electrical Measuring and Test Equipment, Standard for Safety, 1st ed., 1994.

3. Definitions

Refer to ANSI C63.14-1992, IEEE Std 100-1992, and IEC 50 (161): 1990, or latest editions thereof. In case of discrepancies, ANSI C63.14-1992 takes precedence.

4. General

4.1 Basic instrumentation

Each instrument shall consist of a manually or automatically tuned frequency-selective voltmeter with the characteristics as specified in this standard, and as summarized in table 1. Accessory voltage, current, or field sensors shall be available for each type of instrument (see. e.g., table 6).

[6]CISPR documents are available from the International Electrotechnical Commission, 3, rue de Varembé, Case Postale 131, CH 1211, Genève 20, Switzerland/Suisse. CISPR documents are also available in the United States from the Sales Department, American National Standards Institute.
[7]IEC publications are available from IEC Sales Department, Case Postale 131, 3, rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse. IEC publications are also available in the United States from the Sales Department, American National Standards Institute.
[8]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.
[9]SAE publications are available from the Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096, USA.
[10]UL publications are available from Underwriters Laboratories, Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096, USA.

Table 1—Summary of characteristics for quasi-peak, peak, rms, and average EMI instrumentation

Characteristics	0.010–0.15 MHz	0.15–30 MHz	30–515 MHz	470–1000 MHz	1–18 GHz	18–40 GHz	Notes
1. Input impedance	50 and 600 Ω	50 Ω	50 Ω	50 Ω	50 Ω	Standard waveguide	
2. Attenuator range	As required to give on-scale reading for 1 V input	→	→	→	→	→	
3. Output meter range	40 dB minimum	→	→	→	→	→	
4. RF input voltage range	0.5 µV to 1 V	→	→	→	1 µV to 1 V	→	
5. RF sensitivity	0.5 µV	→	→	→	2.2 µV	3.0 µV	INT noise (referred to 50 Ω) ≤ specified level
6. RF preselector	Yes	→	→	→	→	Optional	
7. RF bandwidth	Compatible with IF BW	→	→	→	→	→	
8. RF Dynamic range	80 dB	→	→	→	→	→	
9. Spurious→free dynamic range	60 dB	→	→	→	→	→	
10. LO leakage	5 µV	→	→	→	50 µV	TBD*	Measured without RF attenuation
11. RF tuning overlap	2%	→	→	→	→	10 MHz	For bands within 1 set
12. Overall frequency accuracy	± 2%	→	→	→	→	→	
13. Overall voltage amplitude accuracy	± 2 dB	→	→	→	→	→	Including calibrator
14. Overall field strength accuracy	± 3 dB	→	→	→	→	→	
15. IF bandwidth							
quasi-peak	200 Hz	9 kHz	120 kHz	120 kHz	N/A	N/A	6 dB bandwidth
average, peak and rms	1 and 10 kHz	1 and 10 kHz	10, 100, and 100 and 1000 kHz	100 kHz and 1000 kHz	100 kHz, 1000 kHz, and 10 MHz	→	6 dB bandwidth
16. Linear IF dynamic range (QP)	60 dB	→	→	→	N/A	N/A	
log IF dynamic range (peak)	60 dB	→	→	→	→	→	
crest factor (rms)	20 dB minimum	→	→	→	→	→	
17. Detector time							
Constant quasipeak	45/500 ms	1/160†	1/550 ms	→	N/A	N/A	

Table 1—Summary of characteristics for quasi-peak, peak, rms, and average EMI instrumentation (continued)

Characteristics	0.010–0.15 MHz	0.15–30 MHz	30–515 MHz	470–1000 MHz	1–18 GHz	18–40 GHz	Notes
Detector integrating time							
rms and average	0.1–100 s	→	→	→	→	→	
18. Output Meter							
Time Constant quasi-peak	160 ms	→	100 ms	→	N/A	N/A	
average, rms, peak	Short as possible	→	→	→	→	→	
19. Audio and IF output	Yes	→	→	→	→	→	
20. V_d output (rms detector only)	Optional	→	→	→	→	→	Ratio of rms to average
21. Calibrator	Impulse or sine wave	→	→	→	→	→	
22. Unit of measurement	Microvolt or dB (μV)	→	→	→	→	→	
23. Power supply	100–125V, 48–450 Hz	→	→	→	→	→	Batteries recommended
24. Sensors	Rod, Loop, CP, VP	→	Dipole, Bicon, CLS, CP, VP	→	CLS, WGH	WGH	CLS = conical log spiral CP = current probe VP = voltage probe WGH = waveguide horn
25. Accessories	Yes	→	→	→	→	→	

*TBD = To Be Determined.
†See 10.1.1.

4.2 Units of measurement

The output meter scale shall indicate voltage as an absolute magnitude and in decibels referenced to 1 μV, for example: dB(μV) = 20 $\log_{10}$ ($V \times 10^6$), where V is in volts. Each sensor shall be supplied with calibration curves or tables to convert the indicated voltage to the appropriate electromagnetic quantity being measured. Other optional meter scale units such as μA, dB(μA), pT, dB(pT), μV/m, dB(μV/m) or any other meter-kilogram-second (mks) rationalized units (Système Internationale d'Unites, or SI) may be provided in addition to the required ΩV and dB(ΩV). See annex C for a glossary of terms and abbreviations.

4.3 Instrument calibration

The instrument shall be supplied with sinewave, impulse, or other equally reliable means of substitution calibration for each measured level at any frequency. The substitution voltage shall be available to be applied to either the voltage or field-strength sensor input or equivalent circuit. The instrument shall be supplied with calibration curves or tables that enable measurements of both narrowband and broadband radio interference to the specified accuracies. The basic calibration shall be in terms of the rms value of a sinewave.

5. Frequency ranges

The frequency range of individual instruments may cover any portion of the overall frequency range and may tune below 10 Hz or above 40 GHz. Based upon user applications and radio-frequency spectrum use, it is suggested that individual instruments cover one or more of the following ranges:

a) 10 Hz–20 kHz
b) 10–150 kHz (0.150 MHz)
c) 0.150–30 MHz
d) 30–1000 MHz (1 GHz)
e) 1–18 GHz (or 1–40 GHz)

When the tuning range of an instrument is divided into two or more bands, an overlap of at least 2% between adjacent bands is required, except for the 18–40 GHz frequency range, where overlap shall be not less than 10 MHz. The instrument shall provide continuous coverage within its frequency range.

6. Amplitude range

The two-terminal-voltmeter amplitude range of the instrument shall be from 0.01 ΩV–1 V in the frequency range of 10 Hz–20 kHz; 0.1 ΩV–1 V in the frequency ranges 10–150 kHz and 0.15–1000 MHz; and 1 ΩV–1 V in the frequency range of 1–40 GHz. The total amplitude range is a function of the sensitivity, attenuators, and output-meter range as set forth in the following paragraphs.

For impulsive noise, the input voltage range shall be from at least 50 dB(ΩV/MHz) to 140 dB(ΩV/MHz). The sensitivity shall be measured with a pulse rate of 60 pulses per second ±20% to provide a pulse-count change greater than 2:1 from noise *on* to *off*. The minimum dynamic range of the RF circuits shall be 80 dB and of the IF circuits shall be 60 dB.

A logarithmic (dB) scale having a range of at least 40 dB is desirable. For quasi-peak measurements, a calibrated linear scale shall be provided.

7. Input impedance

The standard input impedance for all instruments for use as a two-terminal voltmeter shall be 50 Ω. If other impedance values are provided, it is recommended that they be standardized at 75, 90, 135, 150, 300, 600, 900, 10 000, and 100 000 Ω. In the 10 Hz–20 kHz frequency range, 600 Ω balanced and 10 000 Ω unbalanced impedances shall be provided in addition to 50 Ω unbalanced. These input impedances may be obtained via external matching networks or internal circuits of the instrument. In the 0.01–0.15 MHz frequency range, a 600 Ω balanced input impedance shall be provided in addition to 50 Ω unbalanced. The minimum balance or common-mode rejection of the balanced input circuit and a method for measurement of this parameter are under consideration.

Above 1 GHz, input voltage standing-wave ratio (VSWR) at control settings for maximum sensitivity typically shall not exceed 2:1, and at no frequency shall exceed 3:1. Above 18 GHz, input connections shall be compatible with standard waveguides.

8. Selectivity and bandwidth

The overall selectivity, sensitivity, and spurious responses are a function of the RF bandwidth and the IF bandwidth. Since each instrument may cover several decades of frequency, several different RF and IF bandwidths may be required. The selectivity shall be obtained without the use of stagger-tuned or over-coupled circuits. As a minimum, the 3 dB and impulse bandwidths must be given as a function of frequency.[11]

8.1 RF bandwidth

An RF preselector shall be used before any amplification stage in each instrument. The bandwidth of each preselector shall be as narrow as possible to reduce spurious responses, and yet wide enough to ensure that the specified overall bandwidth before detection is maintained. RF preselection shall be optional in the optional coverage range or 18–40 GHz.

8.2 Overall bandwidth

8.2.1 Quasi-Peak detector

The bandpass characteristics for each indicated frequency range shall be as shown below, with tolerances as shown in figures 1, 2, 3, and 4.

Frequency range	Bandwidth (–6 dB)
10 Hz–20 kHz	Full range (wideband)
10–150 kHz	200 Hz
150 kHz–30 MHz	9 kHz*
30 MHz–1 GHz	120 kHz

*See 10.1.1.

NOTE — The wideband position is used for certain broadband measurements such as those specified in Section 7 of CISPR Publication 16-1 (1993). (See annex D.)

[11]Methods of measuring the impulse bandwidth are given in IEEE Std 376-1976.

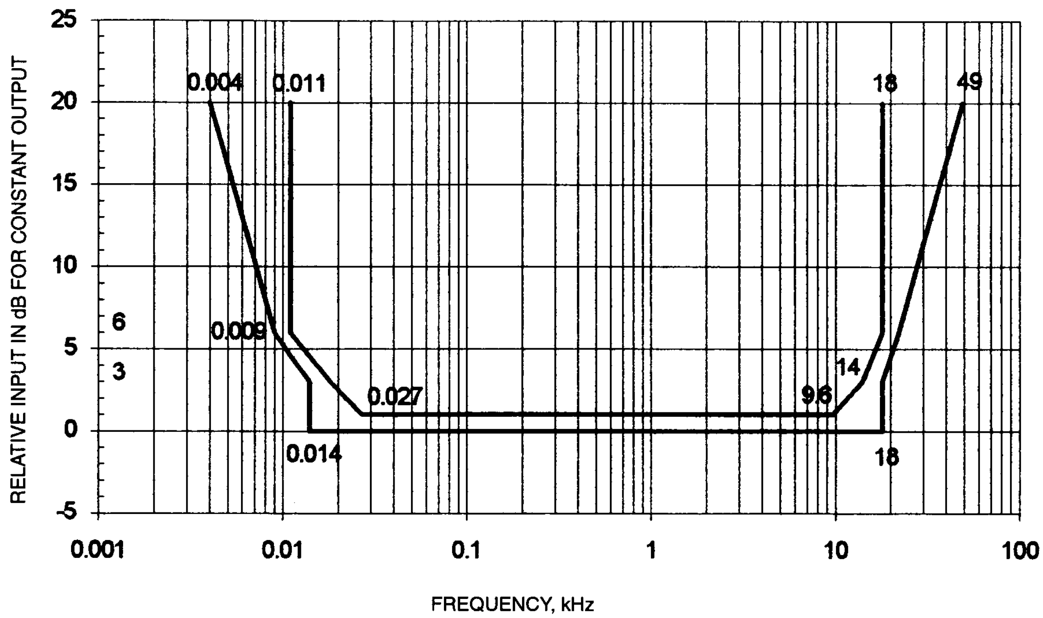

Figure 1—Limits of overall selectivity (passband) in wide band, frequency range, 10 Hz–20 kHz

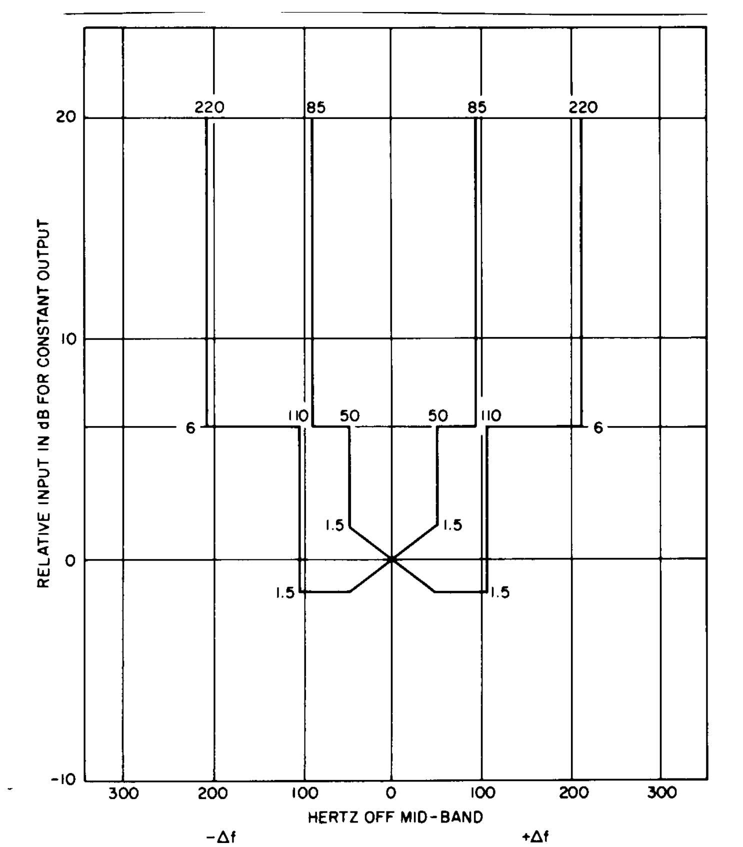

Figure 2—Limits of overall selectivity (passband), frequency range, 0.010–0.15 MHz

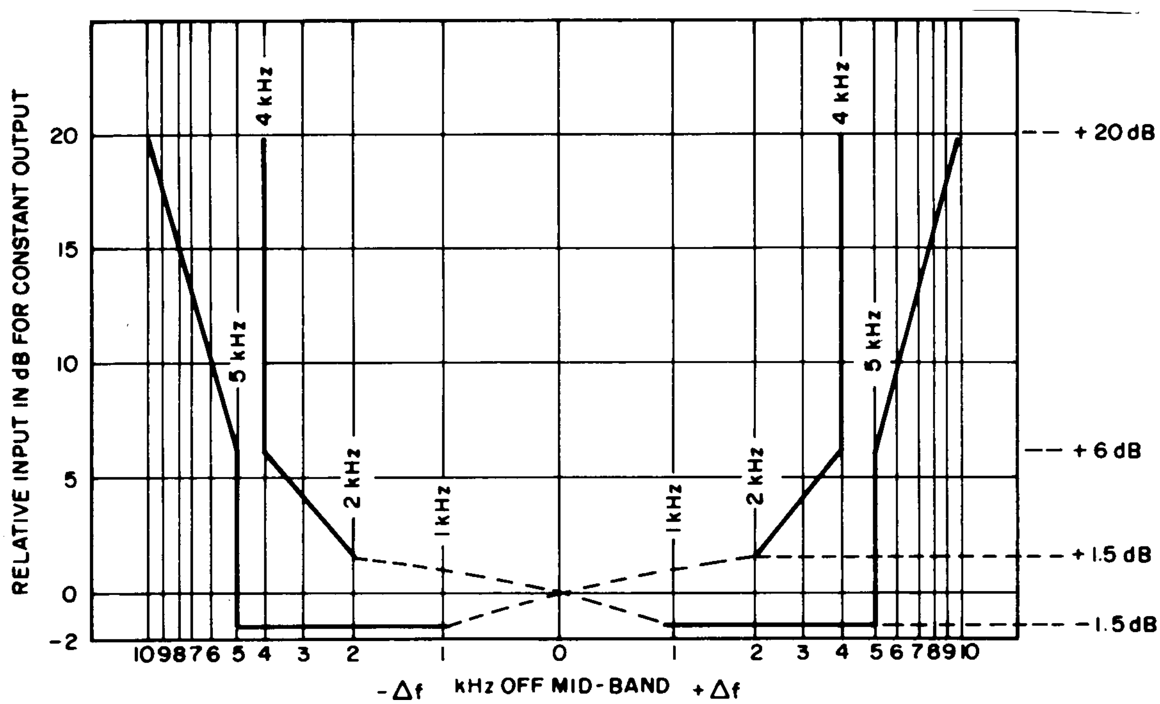

Figure 3—Limits of overall selectivity (passband), frequency range, 0.15–30 MHz

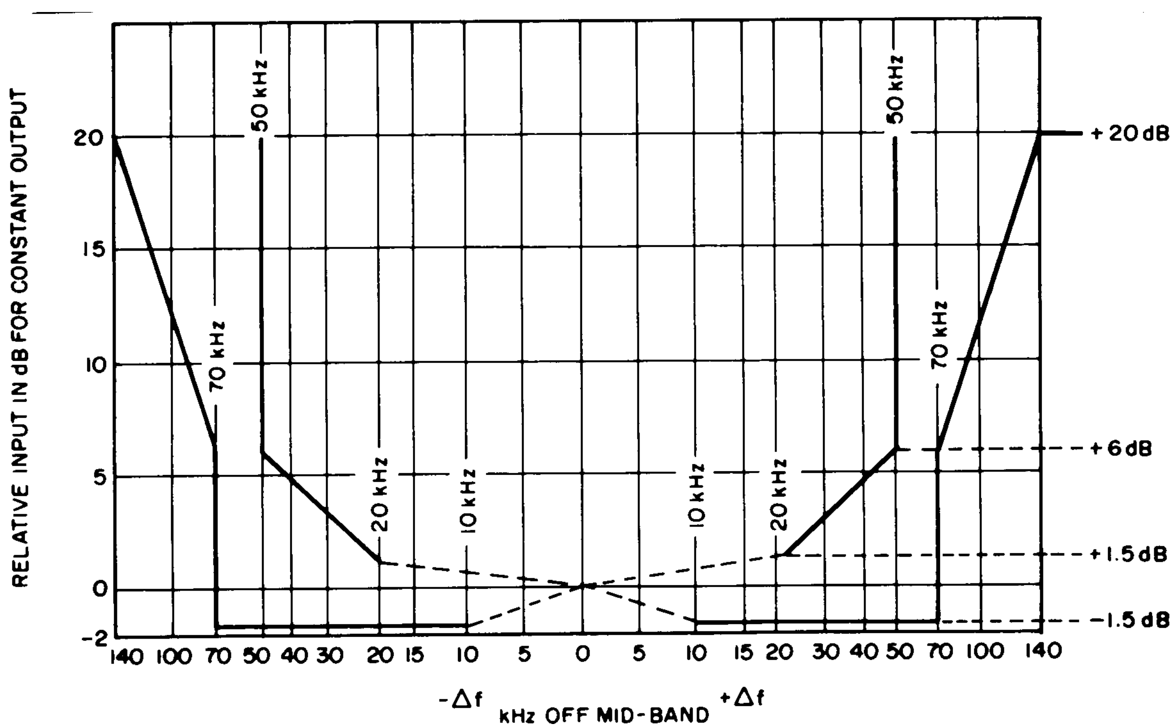

Figure 4—Limits of overall selectivity (passband), frequency range, 30–1000 MHz

8.2.2 Peak, rms, and average detectors

The bandpass characteristics shall be as shown in the following table:

Frequency range	Bandwith* (–6 dB)
10 Hz–20 kHz	10,100, and 1000 Hz
10–150 kHz	1 and 10 kHz
150 kHz–30 MHz	1 and 10 kHz
30 MHz–1 GHz	10 and 100 kHz
1–40 GHz	0.1, 1.0, and 10 MHz

*Tolerance ±10%.

9. Spurious responses

The rejection ratio to signals at frequencies more than 20% from the tuned center frequency shall be 60 dB minimum throughout the frequency range of the instrument. This requirement is applicable to intermodulation, image, IF feedthrough, tuned signal into IF, and similar spurious responses. This requirement is not applicable to image rejection in the 18–40 GHz range.

10. Detector circuits

10.1 Quasi-Peak detector circuit

10.1.1 Circuit time constants

The quasi-peak detector circuit shall have the nominal characteristics for the frequency ranges indicated in table 2.

Table 2—Nominal circuit time constants

Frequency range	Charge time constant*	Discharge time constant*	Optional discharge time constant*
10 Hz–20 kHz	1 ms	160 ms	–
10–150 kHz	45 ms	500 ms	–
150 kHz–30 MHz	1 ms	160 ms	600 ms
30 MHz–1 GHz	1 ms	550 ms	–

*A tolerance of ±20% about these nominal values is suggested.

The charge time constant is the time needed, after the instantaneous application of a constant RF sinewave voltage at the instrument input, for the output voltage to reach 63% of its final value.[12]

[12]Methods of measuring charge and discharge time constants are given in annex A.

The discharge time constant is the time needed, after the instantaneous removal of a constant sinewave voltage applied to the input of the instrument, for the output voltage to fall to 37% of its initial value.

In the special case of interference or radio-influence voltage (riv) measurement associated with electrical power apparatus, interference meters with quasi-peak detector time constants of 1 ms charge and 600 ms discharge and having 6 dB bandwidths of 4.5 kHz are also used at frequencies near 1 MHz. As explained in the note below, such a meter reads essentially the same as one meeting CISPR requirements (1 ms/160 ms time-constants, 9 kHz, 6 dB bandwidth) for most types of electrical discharges [see CISPR Publication 16-1 (1993)].

NOTE — In the United States, radio-interference meters operating at a frequency near 1 MHz are used for quality control and radio-interference measurements from high-voltage (hv) electrical power apparatus, such as extra-high-voltage (ehv) power lines, power transformers and switchgear. The most common interference instruments used in the power industry in the past had quasi-peak detector time constants of 1 ms charge and 600 ms discharge, and 6 dB bandwidths of 4.5 kHz. In contrast, CISPR requirements have quasi-peak detector time constants of 1 ms charge, 160 ms discharge, and a 6 dB bandwidth of 9 kHz [see CISPR Publication 16-1 (1993)].

These instruments, or their equivalents, have been in use for many years, and it has been demonstrated by numerous studies ([B1] ,[13] [B3] , [B4] , and [B5]) both in the US and Europe, that for most electrical discharges associated with power apparatus, measurements with either the US or CISPR instruments will yield almost identical[14] results at pulse repetition rates close to the power frequencies (50/60–180 Hz). At other pulse repetition rates there will be a difference between the two instruments as demonstrated by figure 8 of [B4] . Figure 5 shows the pulse-response characteristic required from an instrument with a 600 ms discharge time.

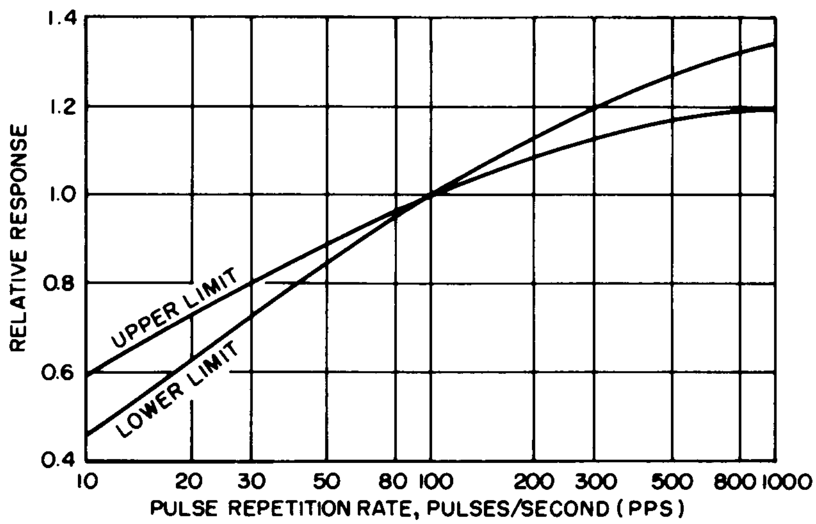

Figure 5—Response characteristic for quasi-peak circuit at 1.0 MHz (Discharge time—600 ms)

10.1.2 Pulse amplitude response

The response of the instrument to pulses of the amplitude specified in table 3, and with a uniform spectrum throughout the frequency range specified, and with a pulse repetition rate as specified shall, for all frequencies of tuning, be equal to the response to an unmodulated sinewave signal at the tuned frequency, from a signal generator having an emf of 2 mV rms and the same output impedance as the pulse generator. When the output impedance of the generator is equal to the impedance of the instrument, the rms sinewave signal at the input to the instrument will be 1 mV.[15]

[13]The numbers in brackets correspond to those bibliographical items listed in clause 20.
[14]This is so because the shorter discharge time constant and wider bandwidth of the CISPR Publication 16 (1987) instrument compensate for the longer discharge time constant and narrower bandwidth of the US instrument. If either the bandwidth or time constants are changed, then measurements with the two instruments would not correlate.
[15]For operational calibration, signals scaled to a lower amplitude may be used.

Table 3—Required pulse amplitudes and pulse repetition frequencies

Frequency range	Pulse amplitude*		Repetition rate
	μVs	dB(μV/MHz)	(Hz)
10 Hz–20 kHz	0.075	94.5	100
10–150 kHz	13.5	139.6	25
150 kHz–30 MHz	0.316	107	100
30 MHz–1 GHz	0.044	90	100

*There is a 3 dB difference between the two values because the calibration is in terms of the value of the rms equivalent sinewave. See annex B.

10.1.3 Pulse-Repetition-Rate response

The response of the instrument with the quasi-peak detector to repeated impulses shall be such that for a constant indication on the instrument, the relationship between amplitude and repetition frequency shall be between the limits shown in table 4. In the frequency range 10 Hz–20 kHz, set the instrument to its wide (16 Hz–16 kHz) bandwidth and insert the "programme" weighting circuit of clause 7.1.3c and figure 6 in CISPR Publication 16-1 (1993). (See annex D.)

Table 4—Pulse-repetition, rate response

Repetition frequency (Hz)	Relative equivalent level of pulse (dB)			
	10 Hz–20 kHz	10–150 kHz	0.15–30 MHz	30–1000 MHz
1000	–4.5 ± 1.0	—*	–4.5 ± 1.0	–8.0 ± 1.0
100	0	−4.0 ± 1.0	0	0
60	—	−3.0 ± 1.0	—	—
25	—	0	—	—
20	6.5 ± 1.0	—	6.5 ± 1.0	9.0 + 1.0
10	—	4.0 ± 1.0	10.0 ± 1.5	14.0 ± 1.5
5	14.5 ± 2.0	7.5 ± 1.5	—	—
2	—	13 ± 2.0	20.5 ± 2.0	26.0 ± 2.0
1	—	17 ± 2.0	22.5 ± 2.0	28.5 ± 2.0
Isolated pulse	23.5 ± 3.0	19 ± 2.0	23.5 ± 2.0	31.5 ± 2.0

*Indicates level is not specified for this frequency range.

10.2 Peak detector

The peak detector shall provide a reading within 2 dB of true peak at a pulse rate of 1 pulse per second for impulse noise with a uniform spectrum across the bandwidth of the instrument. The peak-detector circuit may be one of two types: either Direct Peak (preferred) or Slideback Peak.

10.2.1 Direct peak

The direct-peak-detector circuit shall have a charging circuit with a time constant in seconds that is much shorter than the reciprocal of the widest bandwidth in hertz. The discharge time constant (that is, peak hold) shall be a minimum of five times the time constant of the output indicating device. A peak-hold circuit with dump circuit is recommended.

Manual control of the discharge or dump time constant, either as a step function or continuously variable, is recommended.

10.2.2 Manual slideback peak

The manual slideback-peak circuit can be either a back bias to the detector circuit or a comparator circuit for determining the peak of the noise envelope. Either aural or visual indication of the threshold point may be employed. The bias or comparator signal shall be used to control the output indication of signal level.

10.3 RMS detector circuit

The detector shall provide rms measurement for all types of signal modulation envelopes impressed on the detector. A selectable integrating time-constant range of 0.1–100 s shall be provided.

10.4 Linear average detector circuit

The detector shall provide a linear average measurement of all types of signal modulation envelopes. The calibration is in terms of the rms value of the equivalent sinewave at the tuned frequency. A selectable integrating-time-constant range of 0.1–100 s shall be provided. A calibrated time constant of 1.5 s ± 10% may be provided as an option for certain international tests.

10.5 Audio detector

The instrument shall provide an AM audio detector and a recorder output terminal. In addition, an FM audio detector is recommended for frequencies above 30 MHz. The audio amplifier shall be provided with a manual gain control. The output level shall be 10 mW minimum into a 600 Ω load.

11. Output indicator

The indicator shall be critically damped with time constants of 160 ms for the 10 Hz–30 MHz and 100 ms for the 30–1000 MHz frequency ranges. In this mechanical time-constant specification, it is assumed that the mechanical deflection of the indicator is linear with the input current. The use of an indicator having a different relationship between input current and deflection is not precluded, provided the measuring set meets the requirements of this specification.

The time constant of the indicator can also be defined as being equal to the duration of a rectangular pulse (of constant amplitude) that produces a deflection equal to 35% of the steady deflection produced by a direct current having the same amplitude as that of the rectangular pulse.

12. Overload characteristics

The upper range of practical circuit linearity is the maximum level at which the steady-state response of the circuit departs by more than 1 dB from ideal linearity. The ratio of this level to the level that corresponds to full-scale deflection of the indicating meter is called the overload factor of the circuit considered.

The minimum overload factor of circuits preceding the detector and for circuits between the detector and the output indicator shall be as given in the following subclauses.

12.1 Quasi-Peak detector

With the quasi-peak detector, the overload factors shall be as shown in table 5.

Table 5—Quasi-Peak overload factors

Frequency range (Hz)	Circuits before detector	Circuits after detector
10 Hz–20 kHz	30 dB	12 dB
10–150 kHz	24 dB	12 dB
150 kHz–30 MHz	30 dB	12 dB
30 MHz–1 GHz	43.5 dB	6 dB

12.2 Peak detector

For the peak detector, the overload characteristic is defined by the dynamic range of 60 dB and the spurious-response rejection of 60 dB.

12.3 RMS detector

For the rms detector, the overload factor (ratio of peak-to-rms amplitude of the input signal) shall be 10:1, minimum.

12.4 Average detector

For the average detector, the overload factor shall be at least 5:1.

13. Accuracy

The accuracy of pertinent parameters is described in the specific sections. The overall frequency accuracy shall be ±2%. The overall amplitude accuracy shall be ±2 dB as a voltmeter, and ±3 dB as a field-strength meter.

14. Output devices

In addition to the requirements for the output indicator in clause 11, the following shall be provided.

14.1 Peak detector

The indicator response time and hold time shall be specified.

14.2 Other outputs

Output connectors shall be provided for IF and video. These outputs are intended for connection to a high-impedance oscilloscope, or pulse counter. In addition, it should be possible to connect an external meter, or a 1 mA, 600 Ω input-impedance strip chart, or X-Y recorder to the detector output. These outputs, IF, video, and external metering, shall be available simultaneously. The IF output should provide 60 dB dynamic range. An output level of 1 V (corresponding to full-scale indication) into a 50 Ω load is suggested. The bandwidths of all output circuits shall be consistent with the IF bandwidth in use.

14.3 Digital indicator

A digital output indicator may be used if it provides readings identical to those of the analog device.

15. Sensors

This clause delineates the requirements for coupling devices used to measure voltage, current, power, or field strength.

The requirements of this standard should not be construed to imply that all specified sensors are required for each instrument. The type of sensors to be supplied with each instrument depends upon the user's application. Table 6 shows a listing of suggested sensors to be supplied for each frequency range.

Table 6—Suggested sensors to be supplied for each frequency range

Sensors	10 Hz–20 kHz	10–150 kHz	0.15–30 MHz	30 MHz–1 GHz	1–40 GHz
Rod antenna passive)	Yes	Yes	Yes	No	No
Dipole antenna (passive)	No	No	No	Yes	No
Biconical antenna*	No	No	No	Yes*	No
Log periodic antenna†	No	No	No	Yes†	No
Loop antenna (passive)	Yes	Yes	Yes	No	No
Voltage probe	Yes	Yes	Yes	Yes	No
Current probe‡	Yes	Yes	Yes	Yes‡	No
Absorbing clamp	No	No	No	Yes	No
Waveguide horn	No	No	No	No	Yes
Active antenna**	Yes	Yes	Yes	No	No
Double-ridged guide horn	No	No	No	Yes	Yes

*Usually used only over the 30–220 MHz frequency range.
†Usually used only over 200–1000 MHz frequency range.
‡Current probe may be used up to 100 MHz.
**See 15.5.5 and 15.6.

15.1 Calibration factors

Each sensor shall be provided with the conversion factor that is required to convert the indicated voltage value to the magnitude of the quantity existing at the input of the sensor (that is, volts per meter, amperes per meter, etc.). The conversion factor shall consider all losses between the point of application and the input impedance of the instrument. Except for cables that are an integral part of the sensor, the losses of interconnecting signal cables from the sensor to the instrument shall be stated separately.

15.2 Voltage sensors

Voltage measurements of interference produced by devices or appliances normally connected to power lines are made by the insertion of a line impedance stabilization network (LISN) or artificial mains network between the power source and the equipment under test. The LISN passes power current while preventing the interference from the item under test from appearing in the power source, and preventing power-line electromagnetic interference (EMI) from influencing the measurement. The specific R, L, and C components required for the 50 Ω networks are listed in ANSI C63.4-1992. A line probe as specified in ANSI C63.4-1992 may also be used for voltage measurements under certain conditions.

15.3 Current sensors

Conducted interference current can be measured, without making direct contact with the source conductor and without modification of either the conductor or its circuit, by use of specially developed clamp-on current transformers, also known as current probes. They can be used to measure interference currents in the frequency range of 30 Hz–1000 MHz, although the primary measurement range is 30 Hz–100 MHz. In the vicinity of 100 MHz and above, the standing interference currents in conventional power systems require that the current-probe location be optimized for detection of the maximum interference current. Clamp-on current probes may optionally be designed, calibrated, and used down to 10 Hz.

15.4 Power sensors

An absorbing clamp may be used for measuring interference power conducted along a cable in the 30–300 MHz frequency range. A description of this device and the arrangement for its use are given in ANSI C63.4-1992. The absorbing clamp is fundamentally a current probe with a series of impedance stabilizing ferrite rings, which is positioned on the cable to absorb maximum power.

15.5 Field sensors

15.5.1 Rod antennas

Rod antennas should be no more than 1.5 m in physical length and adjusted to give an effective length of 0.5 m when used in the mounting prescribed by the manufacturer. The effective length shall be determined by the standard-field method in accordance with acceptable standards, such as IEEE Std 291-1991.

NOTE — It is convenient to calibrate the instrument using a rod antenna by applying sinewave voltage through a dummy antenna consisting of a capacitor whose value is equal to the capacitance-to-ground of the rod when used in the mounting prescribed by the manufacturer. Since the effective length is 0.5 m, the field strength in microvolts per meter is equal to twice the applied voltage in microvolts, which produces the same indication of the output meter as the field produced with the rod. The dummy antenna may be used as a high-impedance coupling device for voltage measurements, in which case the capacitor must be able to withstand the line voltage of the circuits on which the instrument is used. See also ANSI C63.5 [see footnote 1].

Although rod antennas are theoretically usable over the 10 Hz–30 MHz frequency range, the coupling loss to typical instrument input circuits is so large at the lower frequencies that they are typically not used below 9 kHz. In any case, the calibration factor shall be supplied for the entire usable frequency range specified by the manufacturer.

15.5.2 Loop antennas

Loop antennas shall be electrostatically shielded. They shall be capable of being rotated at least 180°, independently of the instrument. The manufacturer shall furnish calibration data obtained according to a standard such as IEEE Std 291-1991.

NOTES:

1 — Loop antennas are usually calibrated by placing a second loop antenna carrying sinewave current at a specified distance and calculating the magnetic field at the location of the first antenna. The calculated field is expressed in microamperes per meter. It is desirable to design the instrument with loop antennas to measure the same range of field strengths as with the 0.5 m rod antenna.

2 — It is desirable to provide a shielded loop probe not over 5 cm in diameter for comparative readings only. The probe shall have sufficient insulation over its shielding so that it can be placed safely in contact with devices under test that operate at not over 600 V rms.

Loop antennas are usable over the 10 Hz–30 MHz frequency range. The calibration factor shall be supplied for the entire usable frequency range specified by the manufacturer.

15.5.3 Dipole antennas

Dipole antennas are recommended for the 30–1000 MHz frequency range. The dipole length must be adjusted to resonance at each measurement frequency above 80 MHz. Where used below 80 MHz, the dipole may be used at the tuned length or at the 80 MHz resonant length. In the latter case, an appropriate calibration factor should be supplied in the 30–80 MHz frequency region. The effective length shall also be considered in the conversion factor. IEEE Std 291-1991 provides a method for determining the effective length, and ANSI C63.5 [16] provides the preferred American National Standard calibration procedures for these antennas.

15.5.4 Broadband antennas

Instead of dipole antennas that require mechanical adjustment, broadband antennas may be used above 30 MHz. A biconical antenna for the 30–220 MHz range and a log-periodic antenna for the 200–1000 MHz frequency range are recommended. The preferred calibration procedure for use from 30–1000 MHz is ANSI C63.5, [17] but SAE-ARP-958 may be used. Antenna factors shall be supplied with each antenna.

15.5.5 Active antenna

Active broadband antennas may be used over the entire frequency range in appropriate bands to match the bands and ranges of the instrument (e.g., 10 Hz–20 kHz, or 10 kHz–30 MHz, etc.). The active antennas may be electrically short monopoles (rod antennas), dipole antennas, or loop antennas. Specifications for the intermodulation and overload characteristics are under consideration. However, until added herein, the antenna manufacturers shall provide circuits to indicate or prevent nonlinear operation and/or instructions for the user to determine that the antenna gain factor is not changed by the presence of both in-band and out-of-band signals or emissions. An isotropic (active) dipole may be used to avoid the necessity of orienting the dipole, provided it can be shown that reflections at the test site do not affect the result obtained as compared with a standard dipole.

15.6 Matching networks

In the frequency range of 10 Hz–30 MHz, matching networks are often required when the instrument input impedance is 50 Ω. The matching networks may be passive or active. When active matching networks are provided, the intermodulation and overload characteristics shall be determined. The insertion loss or gain of each network shall also be provided. The following matching networks should be available for purchase with each instrument.

a) 90–50 Ω
b) 135–50 Ω
c) 150–50 Ω
d) 600–50 Ω

[16]See footnote 1.
[17]See footnote 1.

e) 900–50 Ω
f) 10 000–50 Ω
g) 100 000–50 Ω

16. Shielding, filtering, and grounding

The instrument shall be shielded and input circuits shall be filtered so that an electric field of 10 V/m or a magnetic field of equivalent free-space value will not cause any response or undesirable operation within the instrument. The antenna input should be capped during this test. Care should be taken that the shielding is effective for frequencies outside of the frequency range of the instrument. A terminal shall be provided for grounding the instrument.

17. Power supply

The instrument should operate on any supply voltage from 100–125 V (200–260 V is optional) single phase at any frequency from 48–450 Hz. It is recommended that instruments equipped with self-contained batteries be capable of satisfactorily operating continuously for at least 10 h. If batteries must be replaced, serviced, or recharged periodically, the front panel should have a place to record the next servicing date and action. If rechargeable batteries are used, an indicator shall be provided to show the operating time available before recharging is required. In addition, provisions shall be made either to change the internal batteries quickly or to operate from an external battery pack.

18. Safety precautions

Precautions against electric shock hazard shall be taken when an ac operated power unit is used or where an instrument is used to measure hazardous voltages.

A shock hazard is considered to exist as specified in UL 1244, clause 9 Instruments shall be designed to meet UL 1244, UL 3111-1, or an equivalent safety standard, and instrument manufacturers should provide certification that the instrument meets such standard.

Voltmeter terminals or ancillary coupling networks, for use in line-conducted emission measurements, intended for direct connection to power circuits up to 500 Vdc and 250 V rms ac at frequencies up to 800 Hz shall comply with Section 9 of UL 1244. Otherwise, the connection must be made through a capacitor that complies with these requirements.

19. Environmental requirements

Environmental requirements for field-use instruments are under study; the requirements shown in the following table may be changed in the future.

Temperature	0–55°C
Vibration	[B2]
Shock	[B2]
Transportation	[B2]
Moisture resistant	55°C at 90% relative humidity

20. Bibliography

[B1] "A field comparison of RI and TVI instrumentation," prepared by a Task Force of the IEEE Radio Noise and Corona Subcommittee of the Transmission and Distribution Committee, paper no. F76-075-2, presented at the 1976 IEEE Winter Power Meeting.

[B2] EIA Std RS-414-A-1975, Simulated Shipping Tests for Consumer Electronic Products and Electronic Components. (Rescinded; informational only.)

[B3] Harrold, R. T. and Dakin, T. W., "The relationship between the picocoulomb and microvolt for corona measurements on HV transformers and other apparatus," *IEEE Transactions on Power Apparatus and Systems,* vol. PAS-92, no. 1, pp. 187–197, Jan./Feb. 1973.

[B4] Nigol, O., "Analysis of the radio interference from high-voltage lines, parts I and II," *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-83, no. 5, pp. 524–541, May 1964.

[B5] Prauhauser, T. C., "Measurement of Partial Discharges on Transformers and Their Elements, Part B: Comparison of Measuring Instruments and Circuits," CIGRE paper no. 12-10, June 1968.

Annex A Method for determining charge and discharge times of the detector circuit[18]

(Informative)

A.1 Definition of charge time

The charge time is defined as the time required for the voltage on the output of the detector circuit to reach 63% of its final value after a sine wave is suddenly applied at the input of the last intermediate-frequency amplifier stage preceding the detector.[19] The advantage of this definition is that it includes the effects of the impedance reflected into the detector circuit from the coupling and output circuit of the last intermediate-frequency stage.

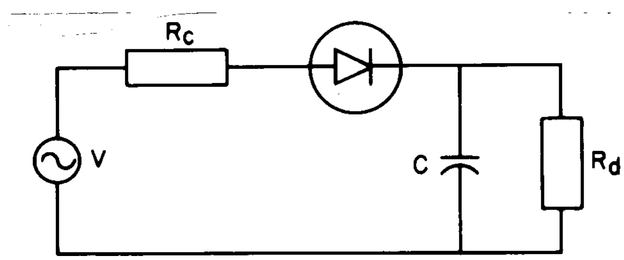

Figure A.1—Typical detector circuit

A.2 Typical detector unit

Figure A.1 is a simplified diagram of a typical detector circuit. Here the final intermediate-frequency amplifier stage and its coupling network to the diode are represented by the equivalent generator V and resistance R_c, where R_c includes the diode resistance (assumed constant during conduction) and the equivalent reflected resistance of the diode input circuit.

A.3 Approximate charge time

The charge time is approximately (within the accuracy required for this specification) given by $4{\cdot}R_c{\cdot}C$ (for closer values, see A.4). The factor 4 arises because the voltage applied to the circuit at V is effective in charging C only while the diode is conducting, and because a sinewave input is used instead of direct current.

A.4 Alternate method for determining charge time

As the technique required to measure charge time according to the definition in A.3 is not always easy to carry out, the following alternative method that determines R rather than the charge time may be used. Witht he automatic-gain-control circuit disconnected from the diode weighting circuit, an unmodulated radio frequency signal is applied at the input terminals of the meter. The discharge resistor R_d is replaced by a variable resistor having a maximum resistance of 10 MΩ or greater. The voltage V_m across the resistor with maximum resistance in the circuit is measured by a high-

[18]The material in annex A is based on information reported in Section A, pages 2–6, of the University of Pennsylvania *Progress Report no. 8 of Investigations of the Measurement of Noise.* A Report of Development Work for the Period 15 March 1947 to 30 June 1947 under Contract NOBS 25397 with the Bureau of Ships, United States Navy, published 30 June 1947, by Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia.
[19]This definition is based on information in CISPR Publication 16-1 (1993).

impedance direct-current voltmeter. The resistance is then adjusted until the voltage across it is 0.5 V_m. This value of resistance R′ is then measured. Then

$R_c = 0.216\ R'$

The product of $3.91 \cdot R_c \cdot$ C is the charge time when the ratio of the charge time to discharge time is 1/160. The product of $4.05 \cdot R_c \cdot$ C is the charge time when the ratio of charge time to discharge time is 1/600.

A.5 Discharge time

The discharge time may be measured by observing the time required for the voltage across R_d to fall to 37% of its initial value after the removal of a sinewave voltage at the input to the measuring set.

A.6 Magnitude of sinewave voltage

In making the foregoing tests, the magnitude of sinewave voltage applied should be such that, in the steady-state condition, full-scale deflection of the indicating meter will be obtained.

Annex B Explanation of pulse amplitude values

(Informative)

The calibration pulse amplitudes are given in amplitude-time area (μVs) and in spectrum amplitude [dB(μV/MHz)]. The value of the amplitude-time area is in terms of the peak value of the pulse since the pulse height, in peak volts, is used in the computation; and this pulse voltage generator emf, i.e., the voltage behind the generator source impedance that is equal, ideally, to the open-circuit output voltage from the generator. Spectrum amplitude is conventionally given in "equivalent rms sinewave," i.e., the rms value of a sinewave having peak voltage equal to the peak value of the pulse and/or its spectrum. In this standard (and many others) it implies a calibration impulse generator (see IEEE Std 376-1976) that is terminated by a load equal to its source impedance.

The following example will explain the calculation needed to convert the listed pulse amplitude-time area to its listed spectrum amplitude. Using the pulse amplitude, 0.075 μVs, for the frequency range from 10 Hz to 20 kHz,

a) Calculate the pulse amplitude across the load of the pulse generator assuming the load impedance is equal to the pulse generator source impedance:

   $(A * t)_L = (A * t)_o/2 = 0.075/2\ \mu Vs$

b) Calculate the peak value of the spectrum amplitude (see IEEE Std 376-1976):

   $(S_f)_{pk} = 2(A * t)_L = 2 \times 0.075/2 = 0.075\ \mu V/Hz$

c) Convert this value to peak spectrum amplitude in μV/MHz by multiplying 10^6:

   $(S_f)_{pk} = 0.075 \times 10^6 = 7.5 \times 10^4\ \mu V/MHz$

d) Convert this value to equivalent rms sinewave by dividing by :

   $(S_f)_{rms} = 7.5 \times 10^4/\ \mu V/MHz$

e) Convert this value to decibels using 20 log $(S_f)_{rms}$:

   $(S_f) = 20 \log [7.5 \times 10^4] - 10 \log[2] = 94.5\ dB\ (\mu V/MHz)$

This is the Pulse Amplitude value in dB listed beside 0.075 μVs in table 3 in subclause 10.1.2.

Annex C Glossary of terms and abbreviations

(Informative)

Table C.1 is not intended to be all inclusive, but to give examples.

Table C.1—Units and symbols

Term	Multiplier	Abbreviation	Decibel
volt	1	V	dB(V)
kilovolt	10^3	kV	dB(kV)
millivolt	10^{-3}	mV	dB(mV)
microvolt	10^{-6}	μV	dB(μV)
nanovolt	10^{-9}	nV	dB(nV)
picovolt	10^{-12}	pV	dB(pV)
volt per meter	1	V/m	dB(V/m)
microvolt per meter	10^{-6}	μV/m	dB(μV/m)
ampere	1	A	dB(A)
microampere	10^{-6}	μA	dB(μA)
ampere per meter	1	A/m	dB(A/m)
microampere per meter	10^{-6}	μA/m	dB(μA/m)
tesla	1	T	dB(T)
picotesla	10^{-12}	pT	dB(pT)
volt-second	1	Vs or V/Hz	dB(Vs) or dB(V/Hz)
microvolt-second	10^{-6}	μVs or μV/Hz or V/MHz	dB(μVs) or dB(V/MHz)
hertz	1	Hz	
kilohertz	10^3	kHz	
megahertz	10^6	MHz	
gigahertz	10^9	GHz	
amplitude modulation		AM	
intermediate frequency		IF	
local oscillator		LO	
radio frequency*		RF	

*In this standard, the term *radio frequency* is used to mean the signal or noise input fequency of the instrument.

Annex D Filter networks (frequency weighting) for radio-frequency interference measurements

(Informative)

Three filter (frequency weighting) circuits are specified in CISPR Publication 16-1 (1993), clause 7.1.3. They are characterized as follows and configured as shown in figure D.1.

a) *Wideband amplifier and quasi-peak voltmeter, 3 dB down at 16 Hz and 16 kHz*. Such filters are typically down 6 dB at 10 Hz and 20 kHz.
b) *Psophometric (telephone) and quasi-peak voltmeter.* Filter characteristic as in Recommendation P.53, Volume V of the Green Book, Fifth Plenary Assembly of the CCITT (Geneva 1972). (See figure D.2).
c) *Psophometric (programme) and quasi-peak voltmeter.* Filter characteristic as in CCIR Recommendation 458 (1974). (See figure D.3).

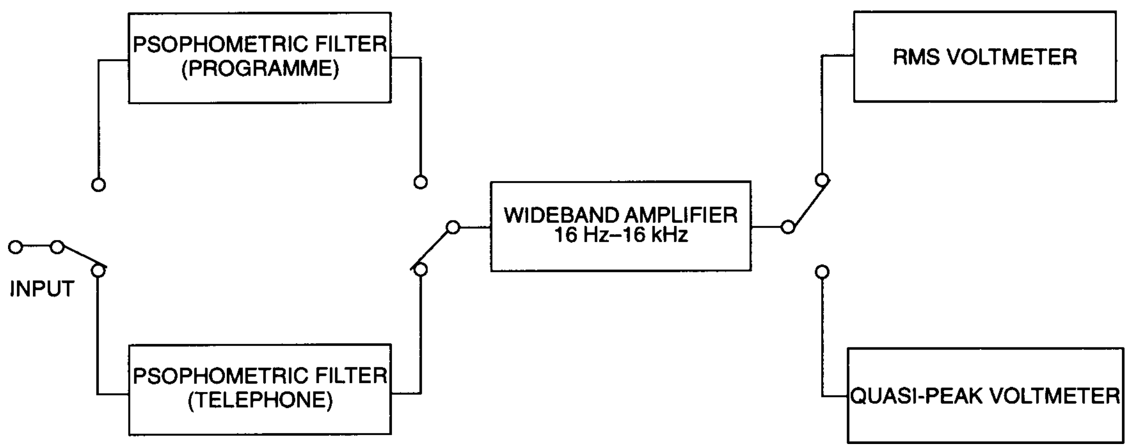

Figure D.1—Block diagram of an audio-frequency interference voltmeter

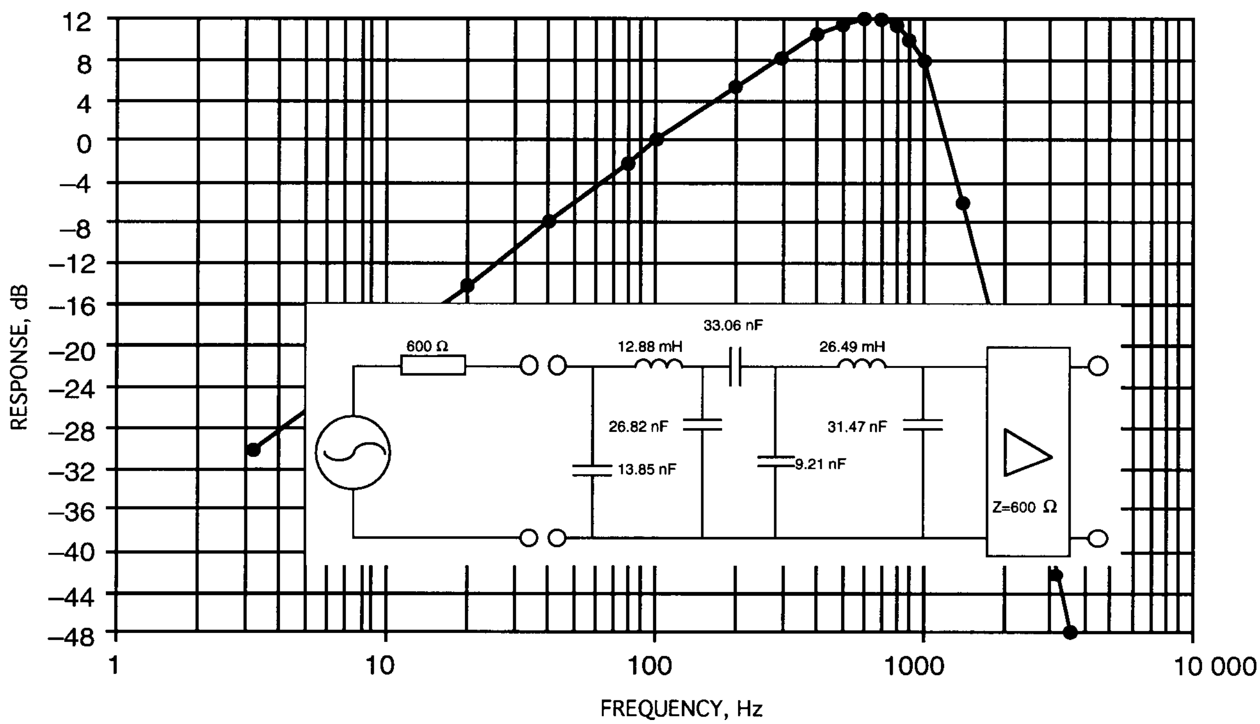

Figure D.2—Characteristic curve of the psophometric filter network used for measurements at the terminals of a commercial trunk telephone circuit

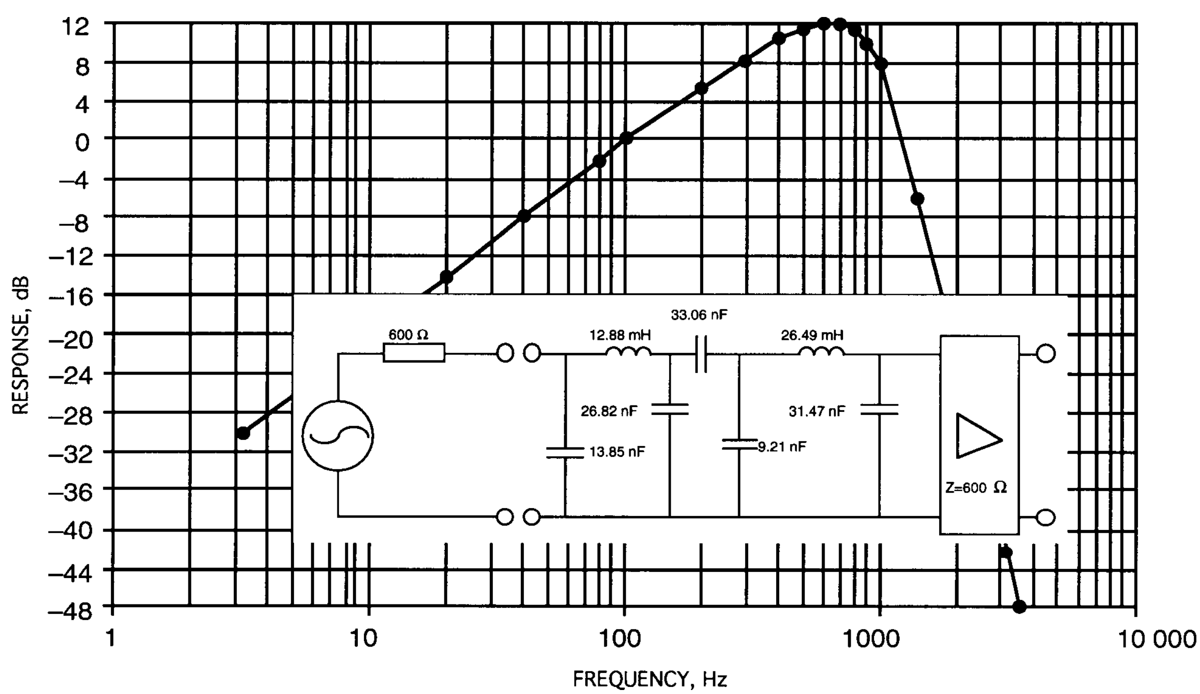

Figure D.3—Weighting network for programme measurements and its response curve

